C5.4 Pretensioned Prestressed Concrete Beam

See the Office of Bridges and Structures web site for archived Methods Memos listed under articles in this section.

The Methods Memos for which policies have been partially revised and/or for which document references have been updated are noted as partially revised. Any obsolete Methods Memos that apply to this section are listed at the end.

The office has redesigned the LXA-LXD, I-shapes to create an A-D beam series that meets the AASHTO LRFD Specifications, and the series has been updated to the fourth edition. The office also has checked and updated the BTC and BTD shapes to the fourth edition and designed and updated the additions to the BT-series, BTB and BTE, to the fourth edition. These designs and checks have been performed with CONSPAN software. All PPCB superstructures and supporting substructures are to be designed by LRFD, and that method has been used to design the transverse reinforcement and the longitudinal deck reinforcement above piers on standard sheets.

This article now covers only the PPCB LRFD superstructure types. The transition to the AASHTO LRFD Specifications is complete, and the Standard Specifications article, which covered standard I and bulb tee shapes used in structures during and since the 1990s, has been withdrawn. The recent series of beams and their status are summarized in Table 5.4.

Table C5.4. Pretensioned prestressed concrete beam series, AASHTO design specifications, and series status

Beam Series	AASHTO Specification	Series Status
LXA-LXD	Standard, 14th Edition	Replaced by A-D series
AM-DM	Standard, 15th Edition	Not to be maintained, for metric projects only
BT	Standard, 15th Edition	Not to be maintained
BTM	Standard, 15th Edition	Not to be maintained, for metric projects only
BTB-BTE	LRFD, 4th Edition	Current
BTCM-BTDM	LRFD, 2nd Edition	Not to be maintained, for metric projects only
A-D	LRFD, 4th Edition	Current, replaces LXA-LXD series

C5.4.1 PPCB LRFD

C5.4.1.1 General

C5.4.1.1.1 Policy overview

Methods Memo No. 159: Policy on Bulb Tee Use
1 June 2008

Methods Memo No. 77: Changes to new BTC and BTD Beams (Supersedes Methods Memo No. 66 in cases of conflict)
14 January 2003

Methods Memo No. 84: New Beam Standard Development
24 July 2003

Methods Memo No. 73: Use of Special Prestressed Beam Designs
30 December 2004

C5.4.1.1.2 Design information

C5.4.1.1.3 Definitions

C5.4.1.1.4 Abbreviations and notation

Methods Memo No. 77: Changes to new BTC and BTD Beams (Supersedes Methods Memo No. 66 in cases of conflict)
14 January 2003

Methods Memo No. 84: New Beam Standard Development
24 July 2003

C5.4.1.1.5 References

C5.4.1.2 Loads

C5.4.1.2.1 Dead

Methods Memo No. 24: Beam Design and Bearing Design, Distribution of Dead Load 2
4 September 2001 (Under LRFD this memo will apply to DC2 and DW loads.)

C5.4.1.2.2 Live

Methods Memo No. 182: LRFD Live Load Distribution for Skewed Bridges with Non-standard Rolled Steel Beams, Non-standard Prestressed Beams or Welded Plate Girders
1 July 2008

Methods Memo No. 40: Exterior Beam Distribution Factor -- LRFD
28 August 2001

C5.4.1.2.3 Dynamic load allowance

C5.4.1.2.4 Earthquake

C5.4.1.2.5 Construction

C5.4.1.3 Load application to superstructure

C5.4.1.3.1 Load modifier

C5.4.1.3.2 Limit states

Memo 5.4.2.3.2, 5.5.2.3.2, and 5.6.2.3.2-2011 ~ Strength V Limit State During Construction and Other Revisions
Based on the description in the AASHTO LRFD Specifications of the Strength V limit state it seemed that it was not intended to be checked during construction. However, a steel plate girder example by M.A. Grubb and R.E. Schmidt distributed nationally by the U.S. Department of Transportation (USDOT) and National Steel Bridge Alliance (NSBA) includes Strength V during construction. The description of Strength V notes: "…plus 1.35 times the design live load (or any temporary live loads acting on the structure when evaluating the construction condition), plus 0.4 times the wind load on the structure, plus 1.0 times the wind on the live load. For evaluating the construction condition under the STRENGTH V load combination, the load factor for temporary dead loads that act on the structure during construction is not to be taken less than 1.25 and the load factor for any non-integral wearing surface and utility loads may be reduced from 1.5 to 1.25." Based on the example and other sources it is clear that Strength V should be checked during construction when appropriate, and articles in the design manual have been

revised with respect to construction limit states. (There are several other changes, also.) The steel example is available at the following URL:

http://www.virginiadot.org/business/resources/SteelDesignExample.pdf

C5.4.1.4 A-D and BTB-BTE beams

C5.4.1.4.1 Analysis and design

C5.4.1.4.1.1 Analysis assumptions

C5.4.1.4.1.2 Materials

Methods Memo No. 80: Maximum Release and Final Concrete Strength for PPCB
15 April 2003

C5.4.1.4.1.3 Design resistance and stress limits

C5.4.1.4.1.4 Section properties

Methods Memo No. 97: Revision of MM No. 83 Camber Calculations Using Transformed Sections for Prestressed Beam Design
21 May 2004

C5.4.1.4.1.5 Deflected strands

C5.4.1.4.1.6 Prestress losses

C5.4.1.4.1.7 Moment

15 March 2012

In the past the Iowa DOT has designed PPCB superstructures by designing the beams for simple spans and detailing for continuity but then also checking the beams in the continuous condition. Generally the beams and deck were adequate for all continuity checks near and at a pier. With development of longer beams, however, service checks at the transfer points and compression checks for negative moment at continuity diaphragms began to fail under some conditions. It also was difficult to place enough tension reinforcement in the deck. As a result the office has decided not to check the continuous condition for concrete compression, taking full advantage of the exception for simple spans in the AASHTO LRFD Specifications [AASHTO-LRFD 5.14.1.4.1].

In order to avoid construction difficulties the office is limiting the reinforcing in the deck so that longitudinal bar spacing is not too close and bars are not too large. In unusual cases these limitations may result in less reinforcement in the deck than would be required for the negative moment at the strength limit state. The office is willing to accept that condition on a case-by-case basis and intends to monitor field performance.

The continuity condition above a pier during service is difficult to determine accurately. Under typical Iowa DOT procedures and specifications the designer has minimal control over the age of beams at the time the pier diaphragm and deck are poured. Effects of creep and shrinkage after the superstructure is continuous also are difficult to quantify even when the age of beams is known. Generally creep and shrinkage effects are relieved at ultimate conditions by concrete cracking and mild reinforcement yielding, and therefore the office considers the exceptions noted above to be reasonable, and the exceptions are permissible under the AASHTO LRFD Specifications.

C5.4.1.4.1.8 Shear

C5.4.1.4.1.9 Deflection and camber

1 January 2015

The following example is intended to illustrate CONSPAN's camber calculation procedure and to demonstrate the use of the recommended camber deflection multipliers from the ISU camber research project. BDM 5.4.2.1.5 contains the research report reference. The prestressed beam standards will be updated to reflect the new camber values in early 2015.

<u>BTE145 Camber Calculation Example</u>
End to End Beam Length = 146.333 ft
Harp Location = (0.35)*(146.333 ft) = 51.217 ft – assume harp points shifted 0.05*L towards beam ends
Beam Height = 63 in
Gross Beam Area = 807.4 in^2
Gross Beam Inertia = 422,790 in^4
Gross Beam C.G. = 28.750 in from bottom of beam
Concrete Unit Weight = 0.150 kcf
Initial Concrete Strength, f'_{ci} = 7.5 ksi
Initial Concrete Modulus, E_{ci} = (33,000)*((0.150 kcf)$^{1.5}$)*(7.5 ksi)$^{0.5}$ = 5250.3 ksi
28-day Concrete Strength, f'_c = 8.5 ksi
28-day Concrete Modulus, E_c = (33,000)*((0.150 kcf)$^{1.5}$)*(8.5 ksi)$^{0.5}$ = 5589.3 ksi
Strand Diameter, d_b = 0.60 in
Strand Area, A_p = 0.217 in^2
Strand Transfer Length = 60*d_b = (60)*(0.60 in) = 36 in
Strand Modulus, E_p = 28,500 ksi
Strand Ultimate Strength = 270 ksi
Strand Jacking Percentage = 72.6%
Modular Ratio, N = E_p/E_{ci} = (28,500 ksi))/(5250.2 ksi) = 5.428 – CONSPAN does not round N

Strand Layout (52 total strands, 42 straight strands, 10 draped strands)

Straight Strands:	12 strands at 2 inches from beam bottom
	12 strands at 4 inches from beam bottom
	12 strands at 6 inches from beam bottom
	6 strands at 8 inches from beam bottom
Draped Strands at Center:	2 strands at 2 inches from beam bottom
	2 strands at 4 inches from beam bottom
	2 strands at 6 inches from beam bottom
	2 strands at 8 inches from beam bottom
	2 strands at 10 inches from beam bottom
Draped Strands at Ends:	2 strands at 52 inches from beam bottom
	2 strands at 54 inches from beam bottom
	2 strands at 56 inches from beam bottom
	2 strands at 58 inches from beam bottom
	2 strands at 60 inches from beam bottom
Draped Strands at Transfer:	2 strands at 49.071 inches from beam bottom
	2 strands at 51.071 inches from beam bottom
	2 strands at 53.071 inches from beam bottom
	2 strands at 55.071 inches from beam bottom
	2 strands at 57.071 inches from beam bottom

Strand C.G. at Center = 4.846 in
Strand C.G. at Ends = 14.462 in
Strand C.G. at Transfer = 13.898 in

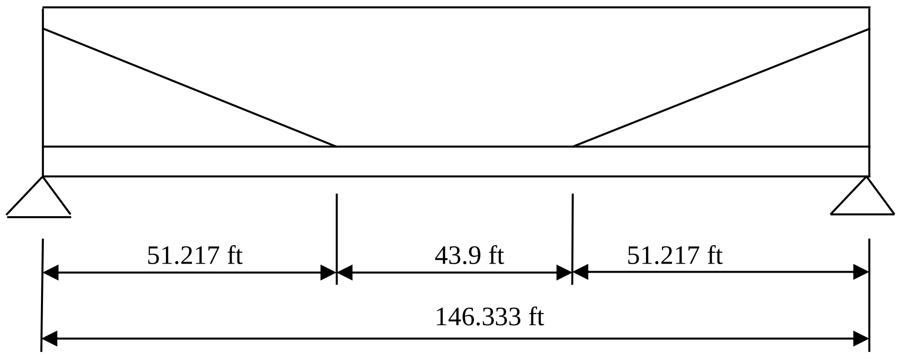
Transformed Beam Properties at Center:

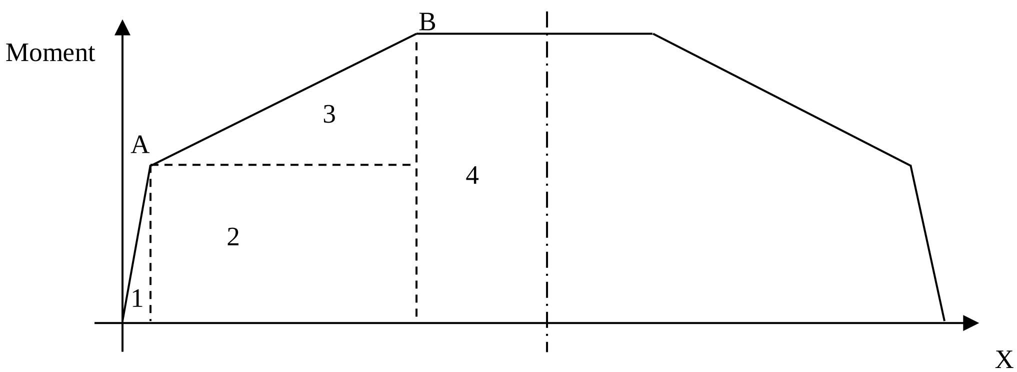
A_t = 807.4 in^2 + (5.428 – 1)*(52 strands)*(0.217 in^2) = 857.4 in^2

Y_{bt} = ((807.4 in^2)*(28.750 in) + (5.428 – 1)*(52 strands)*(0.217 in^2)*(4.846 in)) / (857.4 in^2) = 27.357 in

I_t = 422,790 in^4 + (807.4 in^2)*(28.750 in - 27.357 in)^2 + (5.428 – 1)*(52 strands)*(0.217 in^2)*
(27.357 in - 4.846 in)^2 = 449,677.9 in^4

Strand Force at Release, P_i = (52 strands)*(0.217 in^2)*(270 ksi)*(0.726) = 2211.9 kips





Moment-Area Method -- Point A is the transfer point, Point B is the harp point

M_A = (2211.9 kip)*(27.357 in – 13.898 in) = 29,768.77 kip*in

M_B = (2211.9 kip)*(27.357 in – 4.846 in) = 49,791.16 kip*in

Area		
1	(0.5)*(3 ft)*(29,768.77 kip*in)	= 44,653.160
2	(48.217 ft)*(29,768.77 kip*in)	= 1,435,347.539
3	(0.5)*(48.217 ft)*(49,791.16 kip*in – 29,768.77 kip*in)	= 482,705.305
4	(21.950 ft)*(49,791.16 kip*in)	= 1,092,913.560

Area * X		
1	44,653.160 * (2/3)*(3 ft)	= 89,306.319
2	1,435,347.539 * (3 ft + (0.5)*(48.217 ft))	= 38,909,795.803
3	482,705.305 * (3 ft + (2/3)*(48.217 ft))	= 16,964,372.225
4	1,092,913.560 * (51.217 ft + (1/4)*(43.900 ft))	= 67,969,961.002

Total = 123,933,435.349 kip*in*ft^2

Center Deflection due to Prestress = (123,933,435.349 kip*in*ft^2)*(144 in^2/ft^2) / [(5250.3 ksi)*(449,677.9 in^4)]
= 7.559 in up

Center Deflection due to Self-Weight = 5wL^4 / 384EI = (5)*(0.841 klf)*(1/12 in/ft)*[(146.333 ft)*(12 in/ft)]^4 / [(384)*(5250.3 ksi)*(449,677.9 in^4)]
= 3.675 in down

Instantaneous Camber = 7.559 in – 3.675 in = 3.884 in, close to CONSPAN

Since f'_{ci} > 6 ksi, Initial Camber Deflection Multiplier = 0.95
Initial Camber = (0.95)*(3.884 in) = 3.690 in

Since Initial Camber > 1.5 in, Final Camber Deflection Multiplier = 1.60
Final Camber = (1.60)*(3.690 in) = 5.904 in

C5.4.1.4.1.10 Anchorage zone

C5.4.1.4.1.11 Handling and shipping

C5.4.1.4.1.12 Additional considerations

C5.4.1.4.2 Detailing

Methods Memo No. 99: Update of Bid Item Codes for BTC and BTD
16 July 2004

Methods Memo No. 73: Use of Special Prestressed Beam Designs
30 December 2004

Methods Memo No. 105: Use of Epoxy-Coated Reinforcing Steel
28 March 2005

Methods Memo No. 56: Sealing of PCBM Ends
22 October 2003

Obsolete: Methods Memo No. 36: Miscellaneous Design and Detailing Issues for 71½ (1800 mm) Bulb Tee
7 January 2002

Obsolete: Methods Memo No. 66: Guidelines for Using Standard Prestressed Concrete Beams
27 August 2002 (Much of this memo was superseded by MM No. 77 on 14 January 2003.)

Obsolete: Methods Memo No. 83: Camber Calculations Using Transformed Sections
11 April 2003 (This memo was superseded by Methods Memo No. 97 on 21 May 2004.)

Obsolete: Methods Memo No. 106: End Beam Dimension for BTC
7 February 2005

Obsolete: Methods Memo No. 147: Embedded Deck Hanger Forms in PPCB
15 May 2007 (This memo was superseded by MM No. 197, 1 May 2008.)

Obsolete: Methods Memo No. 183: Policy Regarding Construction Loading
1 January 2008

Obsolete: Methods Memo No. 197: Revision to E/M 202 – Embedded Deck Hangers in PPCB
1 May 2008